Principles of Environmental Restoration

Principle 4 – Managing Uncertainties

Principle 4

Uncertainties are inherent and will always need to be managed

- Session objectives:
  - Be able to identify different types of uncertainty
  - Be able to evaluate tradeoffs between managing uncertainties (contingency planning) and reducing uncertainties (additional data collection or evaluation)
  - Be able to develop an uncertainty management matrix
  - Understand different applications of uncertainty management matrix

Uncertainties encountered in environmental restoration have been inherent in discussions of the previous two principles. This session directly addresses how to analyze and approach these uncertainties

Historically, uncertainty was considered to be addressed once site characterization was complete. Frequently, from this point on, conditions were assumed, and the impact of uncertain site conditions and technology performance was not formally addressed. This workshop takes a broader view of how uncertainties impact the entire environmental restoration process and emphasize the need to plan continuously for these uncertainties

We will continue using the leaking underground tank to illustrate how to conduct uncertainty analyses

Uncertainty management: key concepts

- Understanding the type of uncertainty and its impact on project decisions
- Evaluating tradeoffs between costs of data collection and "decisional benefits" obtained
- Achieving core team consensus to optimally balance:
  - reducing uncertainties through data collection and evaluation
  - "managing" uncertainty through contingency plans

Key concepts focus on:

- Impact of uncertainties on project, i.e., knowing whether you can "afford" to be wrong (and how wrong) or whether you must be right

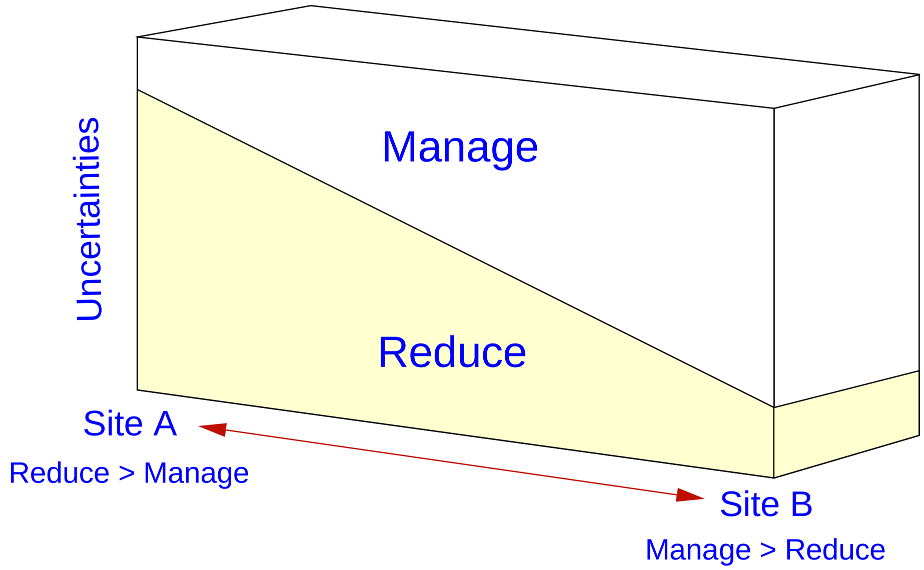
- Tradeoffs between the benefits gained from additional information versus the cost (technical and schedule) to obtain it. The tradeoffs illustrate the central concept of determining when uncertainties can be managed in an effective and efficient manner

- An approach to managing uncertainty should be defined that will provide the balance between reducing and managing uncertainty at the least cost. In some cases, the uncertainty must be reduced to manageable levels through investigation (e.g., review existing data, site characterization, treatability studies). In other cases, the residual uncertainty is manageable by contingency planning (If X happens, then do Y)

- An approach to managing uncertainty must also be acceptable to the core team. The history of a site may make it important to have a wider level of comfort (less uncertainty) than would be acceptable to just the core team or technical project team staff. The process for establishing acceptable levels of uncertainty may include the general public (e.g., a citizens advisory board)

- Consideration of uncertainty starts in scoping and continues through

The balance is site-specific



At some sites (e.g., a site with surface soil contaminated by dioxin), strenuous efforts to reduce uncertainty in advance may pay off in a much more efficient cleanup (Site A)

At other sites (e.g., a heterogeneous landfill), prior characterization may have little benefit, and the challenge is to manage uncertainty during remediation (Site B)

At most sites, both approaches are used to some degree. Optimization means striking the right balance

For any given site, there is a balance of uncertainty reduction and uncertainty management that is optimum with respect to cost, time, or risk objectives

Uncertainties can also be categorized according to their appropriate level of response: (1) those that are insignificant; (2) those that can and should be reduced with more data before a remedy is selected; and (3) those that can and should be managed, during the response with contingency planning

Sources of uncertainty

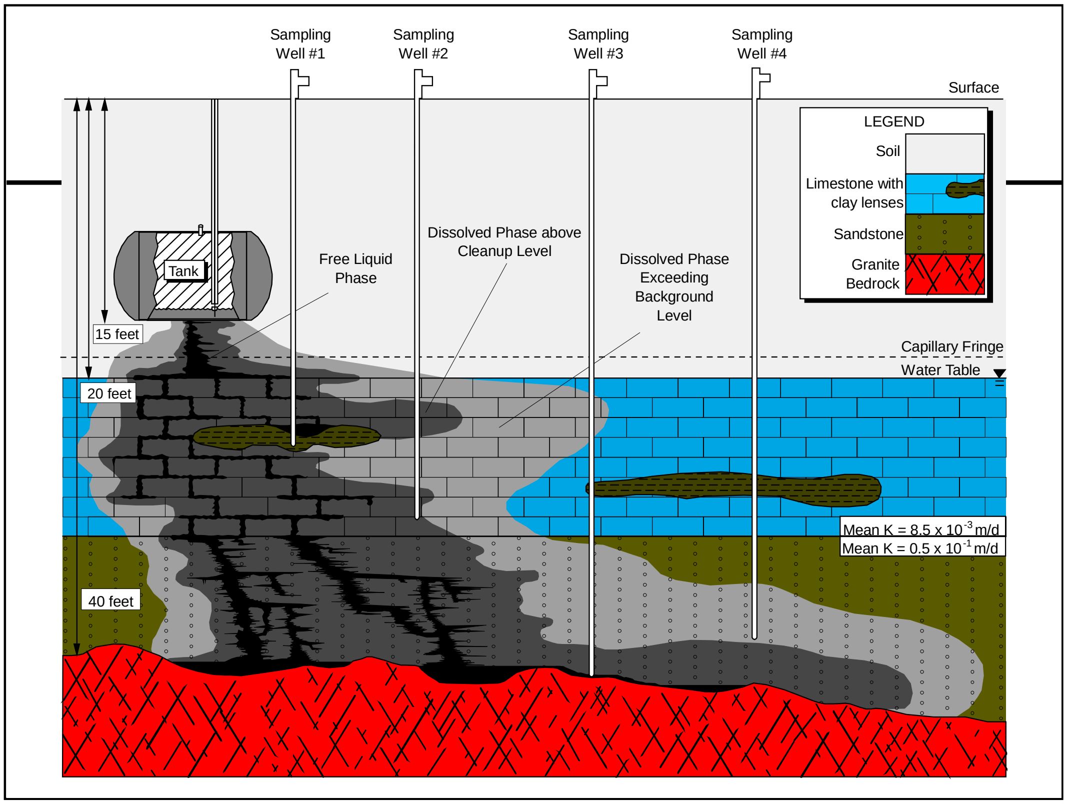
- Site characterization
- Technology selection
- Regulatory requirements
- Administrative processes
- Data analysis

Uncertainties need to be understood to be managed effectively. Organization, documentation, and planning of environmental restoration projects must address these uncertainties

There are numerous ways in which we can be "wrong" or uncertain about a site and its problems. Categorizing uncertainties by source helps to focus on the type of data needed to manage or reduce the uncertainties identified. Five general sources of uncertainty are listed above

These sources of uncertainty are interrelated. For example, uncertainties in site characterization lead to uncertainties in whether a technology will work and what regulations apply. Uncertainties in technology performance can lead to uncertainties in regulatory compliance

Using the hypothetical leaking tank example, the remainder of this session discusses how to think about, categorize, and respond to uncertainties



What are the major uncertainties posed by this scenario?

Impact of uncertainties

- An uncertainty can be:
  - Insignificant to implementing the project and solving the problem
  - Significant and needs to be:
    - reduced prior to response (i.e., data need); or
    - managed during the response through contingency planning

Insignificant uncertainties for a given problem (i.e., those that do not affect the overall direction of the project) are not necessarily trivial. For example, if a storage area has a capacity of 100,000 cubic yards and a response will only generate between 3,000 and 10,000 cubic yards, the volume of material to be generated is insignificant to the response. However, using up to 10 percent of available capacity for one response may create other sitewide issues

There are two types of insignificant uncertainties:

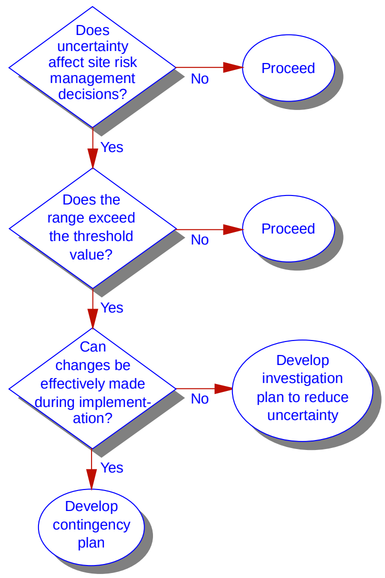
•Those insignificant due to the nature of the uncertainty

•Those insignificant because the range of possible or likely values falls below the threshold at which a response is necessary

Uncertainties that must be reduced prior to an action results in a data need. The data may be obtained prior to implementation of a remedy (e.g., site characterization, pilot-scale treatability study), or it may be possible to collect the data in a post-decision design investigation

Uncertainties that can be managed effectively are those that can be addressed through a contingency plan. These contingency plans are included in decision documents, or subsequent design documents

Uncertainty management approach



The impact of an uncertainty will correspond to a specific management approach

The approach to managing uncertainty will include both reducing and counteracting uncertainty. The challenge is to reach core team consensus in establishing the balance between the two components

Organizing uncertainty information

- Uncertainty can be characterized by the following information
  - Likely or expected condition
  - Reasonable deviation from the expected condition
  - Probability of occurrence
  - Time to respond
  - Potential impact on problem response/resolution
  - Monitoring plan
  - Contingency plan
- Uncertainty management changes emphasis from assessment to implementation

Characteristics of uncertainty:

- The likely condition is the expected or probable condition. Based on current data and assumptions, it is reflected in the conceptual site model, and is the basis for planning the response action

- Reasonable deviation from the expected or probable conditions is used to express uncertainty either quantitatively or qualitatively

- Evaluating uncertainty includes consideration of a) the likelihood of occurrence, b) the timeframe to respond, and c) the potential impacts of reasonable deviations from expected conditions

- Monitoring/investigation are the kinds of observations or measurements that will be taken to determine if the uncertain condition (or reasonable deviations) is present. Using the threshold example, the monitoring would involve sampling to detect the presence of other contaminants

Categorizing impacts of uncertainties:

Example Decision Rule: If the underground tank is continuing to release TCE and Tc-99 to the environment, as indicated by liquid in the tank, remove tank

Probable Condition	Reasonable Deviation	Probability of Occurrence	Time to Respond	Potential Impact	Monitoring/ Investigation	Contingency Plan
Saturated soil conductivity expected to be 10E(-4) cm/s	Conductivity likely to range from 10E(-2) to 10E(-7) cm/s	High. (based on existing hydro-geologic data)	Long.	Low. May impact the drainage of rainwater if < 10E(-4) cm/s	N/A	**Insignificant.** No impact on likely response action.
Soil is expected to be stable (i.e., greater than Class C)	Soil may be unstable (i.e., slump slope < 50% or soil is less stable than Class C)	Low. (based on results of previous slump tests)	Short. (excavation face may sluff or cave in)	High. - Threat to worker safety - Could increase cost or delay schedule	Conduct visual inspections and additional slump tests	**Significant.** - Shore walls - Lay back excavation
Tank and its contents are expected to be low-level waste	Subtitle C debris management rule may be applicable (i.e., tank/contents could be hazardous or mixed waste)	Medium. (based on process knowledge)	Short. (to prevent excavation from being delayed)	High. - May delay excavation - May increase disposal costs and change handling requirements	Sample and analyze tank contents; compare results to regulatory criteria	**Significant.** Develop contingency plans for excavation, storage, and disposal of hazardous and mixed wastes; analyze cost impacts to ensure available funding.

The matrix above focuses on uncertainties associated with the implementation of a likely response action, and illustrates the classification of identified uncertainties into the categories listed below:

•Uncertainty insignificant to ultimate objective

•Uncertainty must be reduced with more data

•Uncertainty, but can be managed by contingency plan

Probable condition identifies nature of the uncertainty that exists

Reasonable deviation from the expected condition is a quantitative or qualitative expression of uncertainty

Probability that a deviation will occur, timeframe to respond to a deviation, and potential impacts of a deviation on the likely response are all considered in evaluating uncertainty

Monitoring/Investigation are the kinds of observations or measures that will be taken to determine the existence of an expected condition or reasonable deviations

Contingency plan documents how an uncertainty will be managed - either by reducing it or developing a contingency plan

Documenting uncertainty using decision rules

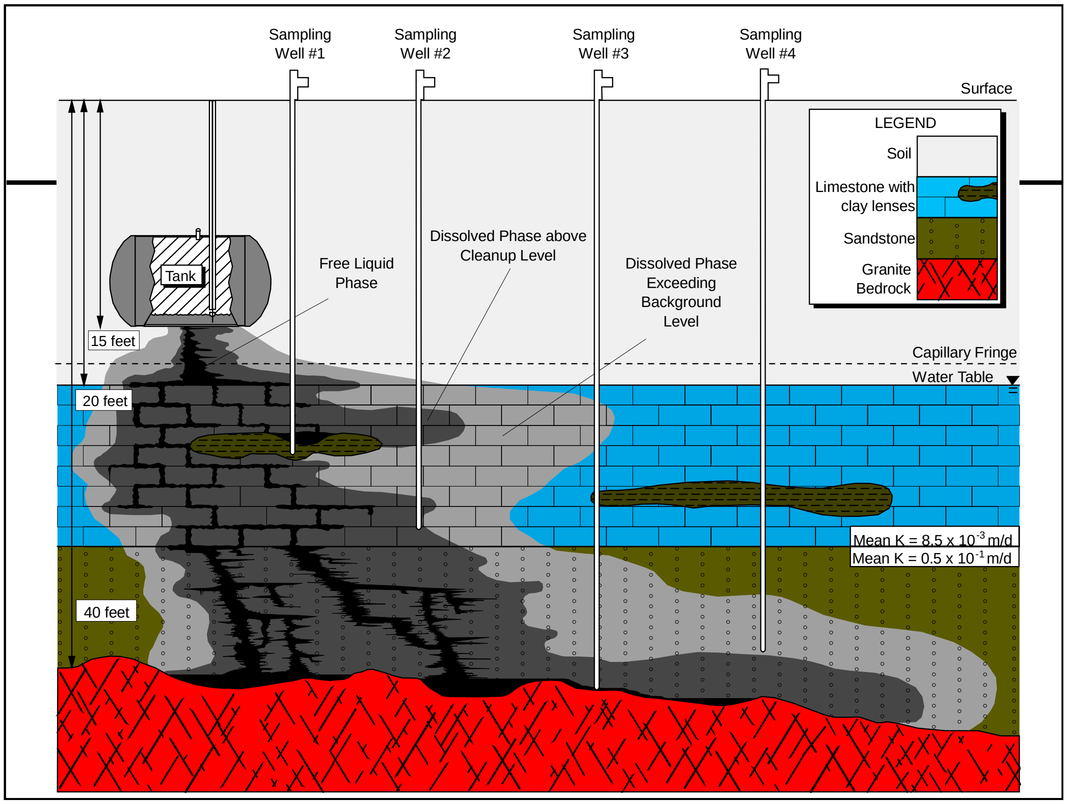
- Uncertainty: Is the tank a mixed low-level waste?
- If the tank is excavated and cannot be managed under RCRA debris regulations, then manage as a mixed waste; otherwise, manage as a low-level waste

As with problem definition and early identification of response actions, decision rules can be used to document uncertainties, particularly when the decision is to manage by contingency plans

RCRA Debris rule allows most types of debris containing hazardous wastes to be treated using appropriate technologies and, following treatment, be rendered non-hazardous

In this case, if the debris rule was able to be applied to the tank, the tank would be considered to be low-level waste following treatment rather than mixed waste

The determination of whether the tank could be managed under the debris rule would involve (1) status of the debris rule under State hazardous waste regulations; (2) technical ability to manage the contaminated tank using the appropriate technologies. For example, if a tank were corroded or not intact, washing technologies to remove hazardous wastes may not be technically appropriate



For this scenario, would you want to counteract or reduce the following uncertainties?

How would you state your decision rule if you decide to manage?

1. Level of water table relative to tank

2. Location of TCE pools

3. Contents of the tank (i.e., Are contents present? What are their physical nature and regulatory status?)

4. Condition of the tank

In summary: What does categorizing uncertainties do?

- Forces explicit statements and consensus on uncertainties that may exist
- Establishes agreed to approaches to manage uncertainties
- Makes explicit the needs for data collection and/or contingency planning
- Helps document how the response will proceed

Lack of explicit recognition of uncertainties, lack of consensus, and lack of planning on how to proceed will create substantial project management and project performance issues

Once problems are defined, data collection, studies, investigations, and analyses should be focused on identifying and planning on how to respond to uncertainties

Uncertainty analysis needs to be explicitly communicated and agreed to among core team members

Again, interest may extend beyond the core team

The more explicit we are in what uncertainties exist, what their impact is, and how we will deal with them, the more likely it is that we can reach a consensus. Uncertainty issues are the source of most of the differences in opinion

Small group exercise

- Review the materials for the pipe-in-trench example
- Identify uncertainties that exist
- Categorize the uncertainties in a matrix
- After 45 minutes, we will discuss the results

Problem 1: Pipe containing sludges that could provide a continuing source of Cs-137 to surface soils and stream sediment in concentrations greater than health-based levels

Evaluate Likely Response Actions (select among alternatives):

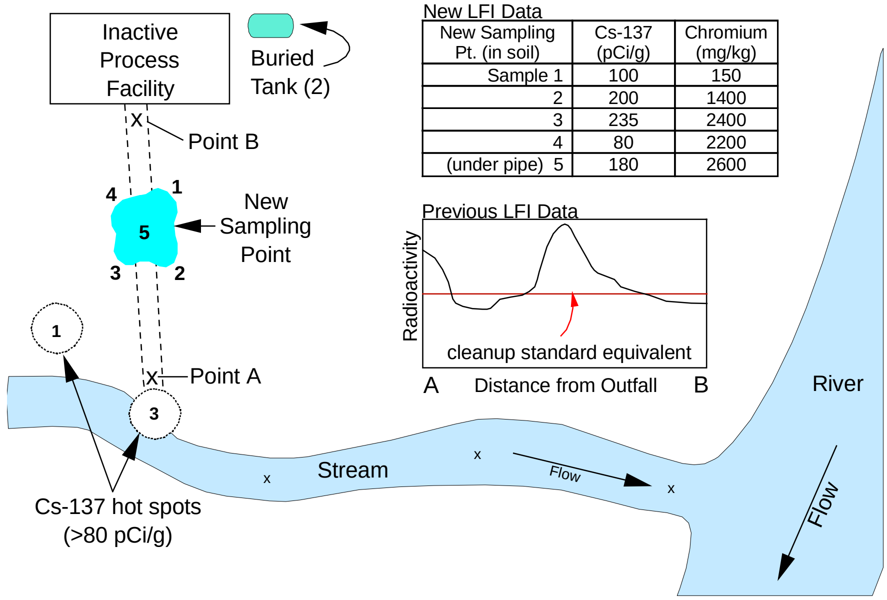
- Remove the sludges contaminated from the pipe in excess of regulatory or health-based levels
- Grout pipe
- Remove pipe

Problem 2: Cs-137 and chromium released to soil in excess of health-based and regulatory levels

Likely Response Action (implement selected alternative):

- Excavate soils containing Cs-137 and chromium in excess of regulatory levels

Pipe-in-trench problems



New LFI Data

New Sampling Pt. (in soil)	Cs-137 (pCi/g)	Chromium (mg/kg)
Sample 1	100	150
2	200	1400
3	235	2400
4	80	2200
(under pipe) 5	180	2600